Internship project proposal for MISIP 2026

1) **Project title: Electrical conductivity measurement of Fe-rich garnet with implications of high electrical conductivity in the deep Lunar interior**
2) Supervisors (*corresponding): Takashi Yoshino
3) Number of students: 1
4) Detailed description of the project (including aim, detailed plan and expected outcome):

The internal structure and composition of the Moon have been subjects of intensive investigation since the Apollo era. One of the most compelling findings regarding the lunar deep interior is the observation of anomalously high electrical conductivity near the core-mantle boundary (CMB). Based on the electromagnetic sounding data obtained from the Apollo 12 and 15 surface magnetometers, combined with orbital data from Explorer 35, researchers have identified a significant increase in conductivity at depths exceeding 1,000 km. Initial analyses suggested that the conductivity in the lowermost mantle reaches levels as high as 0.1 S/m or greater. This value is substantially higher than what would be expected for a standard solid silicate mantle. Recent integrated studies using both seismic and magnetic data (Khan et al., 2014) have confirmed the existence of this high-conductivity zone, which appears to correlate with the seismic low-velocity zone (LVZ) identified by Weber et al. (2011).

The presence of such high conductivity is typically interpreted through two primary mechanisms: the presence of a partial melt layer enriched in incompatible elements (such as Ti or Fe) or a change in mineralogical composition, such as an accumulation of garnet-rich or ilmenite-bearing materials. Understanding the precise origin of this conductivity is crucial for constraining the thermal history and the current state of the lunar core and deep mantle. It has recently been shown that iron-rich garnet layers form at the bottom of a magma ocean through fractional crystallization. However, Fe-rich garnet layer is high in density, creating a discrepancy between observed low velocities. Electrical conductivity serves as a powerful discriminator to break the degeneracy of seismic data. By measuring the electrical conductivity of Fe-rich garnet in laboratory settings and comparing it with lunar electromagnetic sounding data, we can determine if the LVZ is caused by a solid composition or a melt-bearing layer.

Plan

1) Synthesis of aggregates of Fe-rich garnet in gas-controlled furnace
2) Phase identification by XRD, SEM and EPMA
3) In situ electrical conductivity measurements of synthesized sample at the core-mantle boundary condition by impedance spectroscopy
4) Post-experimental analysis of recovered samples
   The recovered samples will be analyzed using backscatter electron imaging, X-ray diffraction, and electron microprobe analyzer (EPMA) before and after the conductivity measurements.

References

A. Khan, J.A.D. Connolly, A. Pommier, J. Noir, 2014. Geophysical evidence for melt in the deep lunar interior and implications for lunar evolution. J. Geophys. Res.: Planets, 119, 2197-2221

G. Kraettli, M.W. Schmidt, C. Liebske, 2022. Fractional crystallization of a basal lunar magma ocean: A dense melt-bearing garnetite layer above the core? Icarus, 371, 114699.

R.C. Weber, P.-Y. Lin, E.J. Garnero, Q. Williams, P. Lognonn, 2011. Seismic detection of the lunar core, Science, 331, 309–312.

Internship project proposal for MISIP 2026

1) Project title: Water in nominally anhydrous mantle mineral (stishovite): high-PT synthesis and spectroscopic characterization
2) Supervisors (*corresponding): Xianyu Xue* and Takayuki Ishii
3) Number of students: 1
4) Detailed description of the project (including aim, detailed plan and expected outcome):

Background & Aim: Water, even when present in trace amounts in 'nominally anhydrous' major mantle minerals, could have significant effects on mantle properties. Thus, a large number of studies have been conducted so far to investigate the influence of incorporated water on various physical properties (e.g., elastic properties, electrical and thermal conductivities) for major mantle minerals, often with controversial results. As the effects of water on mineral properties strongly depend on how it is incorporated in the crystal structure, a fundamental understanding of the structure and its correlation with physical properties is indispensable. Most of the structural studies on water incorporation in 'nominally anhydrous' minerals have been carried out using infrared (IR) spectroscopy. The interpretations are, however, often controversial.

On the other hand, our studies using combined multi-nuclear nuclear magnetic resonance (NMR) and vibrational spectroscopic measurements, and first-principles calculations on nominally anhydrous minerals have turned out to be very successful, and provided unambiguous evidence for the incorporation mechanisms and concentrations of water in minerals such as Mg_2SiO_4 forsterite (MISIP 2015; Xue et al. Am Mineral 2017, 102, 519-536), $MgSiO_3$ enstatite (MISIP 2016; Xue et al. Contrib Mineral Petrol, 2024,179, 33) and aluminous enstatite (MISIP 2023; Xue et al., Contrib Mineral Petrol, 2024, 179, 104; Xue & Kanzaki Contrib Mineral Petrol, 2024, 179, 105). Our long-term goal is to extend the study to all major mantle minerals for a total understanding.

This internship project is a small part of our large ongoing project toward this goal, and will focus on one of the potentially important water carriers to the deep mantle, SiO_2 stishovite. Despite previous studies, it is still controversial how much and in what form, water is incorporated in the mineral structure of stishovite.

Detailed Plan:

(1) Sample synthesis: Water-bearing SiO_2 stishovite will be synthesized at high P-T (around 9-10 GPa, 450˚C) in a large-volume multi-anvil press. Depending on progress, sample synthesis at other P-T conditions may also be carried out.

(2) Spectroscopic measurements: ^{1}H and ^{29}Si NMR, and micro-Raman and/or micro- Fourier-transform (FT)-IR will be used for characterization of the synthesized samples. Other techniques, such as EPMA/SEM-EDS and X-ray diffraction (XRD) may also be used depending on progress.

FT-IR is a commonly used tool to examine water incorporated in the mineral structure (OH stretching vibrations), and thus provide ready comparison with literature IR data. Raman can also reveal OH stretching vibrations, and is also a convenient tool for phase identification.

NMR can provide not only quantitative information about the bulk water content, but also rich information that may constraint how water is incorporated in the structure.

EPMA and SEM-EDS can be used for analyzing chemical compositions of individual phases and mapping of phase distribution and texture. XRD may be used for phase identification, and also provide information of crystal structure.

(3) *(Optional)* First-principles calculation of structure, NMR and vibrational characteristics of the mineral using the Quantum Espresso package.

Such calculations are becoming reliable enough and indispensable to guide interpretations of experimental NMR and vibrational spectroscopic data.

Expected Outcome:

It is hoped that this internship project will yield exciting new insights into how water is incorporated into the studied mineral, which will constitute an important first step toward a complete understanding of the problem.

Internship project proposal for MISIP 2026

1) Project title: Water transport into the deep Earth and its link to deep-focus earthquakes
2) Supervisors (*corresponding): Takayuki Ishii
3) Number of students: 1
4) Detailed description of the project (including aim, detailed plan and expected outcome):

Water plays a fundamental role in shaping the dynamics and evolution of our planet. Even small amounts of water can drastically lower the melting temperature of mantle rocks, influence volcanic activity, and affect the strength of materials inside the Earth. A key pathway for transporting water into the Earth's interior is the subduction of oceanic plates, which contain hydrous minerals within basaltic crust, harzburgite, and peridotite. However, how much water actually reaches the deep mantle remains one of the major unsolved questions in Earth and planetary sciences.

Hydrous minerals—minerals that contain water in their crystal structure—are thought to be the most efficient carriers of water to great depths. Yet, their stability, breakdown reactions, and exact phase relations under realistic slab conditions are still poorly constrained, especially for complex natural rock compositions. These uncertainties limit our understanding of the deep-water cycle and its connection to geophysical phenomena.

One particularly intriguing link is the occurrence of deep-focus earthquakes, which originate at depths of 300–700 km—far below the range where brittle failure is expected. One leading hypothesis is dehydration-induced embrittlement, where hydrous minerals break down under high pressure and temperature, releasing water and triggering seismicity. Harzburgite, which forms a major part of the cold slab interior, may host significant amounts of these hydrous phases.

In this project, you will investigate the phase relations of hydrous harzburgite along realistic slab geotherms down to ~700 km depth. By conducting high-pressure experiments and analyzing the resulting mineral assemblages, you will help clarify which hydrous minerals can survive to great depths and how their breakdown might relate to deep-focus earthquakes.

You will contribute to improving our understanding of how water is stored and released inside subducting slabs. The results may provide new insights into the mechanisms behind deep-focus earthquakes and the long-term evolution of Earth's interior.

Plan

1) Preparation of hydrous harzburgite starting materials
2) High-pressure experiments using a Kawai-type multi-anvil press
3) Phase identification and textual and chemical analysis using X-ray diffraction, scanning electron microscope, and electron microprobe analysis
4) You will evaluate the stability of hydrous phases, estimate water transport efficiency, and discuss implications for deep-focus earthquakes and the global deep water

Related references

Ishii, T., Zhu, J., & Ohtani, E. (2025). Limited water contents of wadsleyite and ringwoodite coexisting with hydrous minerals in cold subducting slabs. *Earth and Planetary Science Letters*, *658*, 119310.

Ohtani, E., & Ishii, T. (2024). Role of water in dynamics of slabs and surrounding mantle. *Progress in Earth and Planetary Science*, *11*(1), 65.

Internship project proposal for MISIP 2026

1) Project title: Understanding mineral-organic relationships through soluble organic matter imaging and comparison with in-situ analytical data.

2) Supervisors (*corresponding): Christian Potiszil*, Katsura Kobayashi, Ryoji Tanaka, Tak Kunihiro, Hiroshi Kitagawa, Tsutomu Ota, Masahiro Yamanaka and Chie Sakaguchi.

3) Number of students: 3

4) Detailed description of the project (including aim, detailed plan and expected outcome):

Carbonaceous chondrite meteorites represent some of the most well studied primitive meteorites in our collections on Earth. Among this group of carbonaceous chondrites, the Murchison meteorite is one of the most investigated meteorites in the world. Meanwhile Aguas Zarcas, represents a relatively new CM2 chondrite, having fallen in Costa Rica in 2019. While much has been revealed about Aguas Zarcas, the distribution of its soluble organic matter remains unclear. During this internship program, successful applicants will investigate the differences in the distribution of soluble organic matter and relate this to petrological e.g. chondrules, chondrule rims and matrix phases), mineralogical (e.g. olivine, pyroxene, phyllosilicate etc…) and insoluble organic phases, elemental and isotopic data (e.g. C, N and H). This work will be undertaken in order to better understand mineral-organic relationships, which can tell us how both the organic and inorganic phases evolved within carbonaceous chondrite progenitor planetesimals.

The internship students will work together in a team to undertake desorption electrospray ionization-Orbitrap mass spectrometric (DESI-OT-MS) analyses of Aguas Zarcas and Murchison samples, which have already been extensively studied by other in-situ techniques. Further in-situ analysis may be required if interesting soluble organic matter responses are observed for regions where data in not available. Therefore, SEM-EDS, EPMA and Raman spectroscopy may also be employed to complete the data sets.

While the students will be mainly working on soluble organic matter utilizing DESI-OT-MS, they will be exposed to an array of different analytical techniques and set-ups, as well as lab environments. Such experience will greatly contribute to the student's scientific experience and aid them in a future career in science, whether that be in academia or industry. A large comprehensive data set will be investigated and the students will gain valuable data analysis and interpretation skills. In terms of the scientific outcomes, the students will help to determine whether there are any relationships between soluble organic matter and physical features, mineral and insoluble organic phases, elemental composition, or sample regions with distinct stable isotope compositions. Through this investigation interesting relationships will be revealed and explanations explored. Overall, such information will improve our understanding of the formation and evolution of CM chondrites and our solar system.

Internship project proposal for MISIP 2026

1) Project title: **Planetary Surface Studies Using Remote Sensing, Experiments, and Geophysics**
2) Supervisors (*corresponding): ***Trishit Ruj; *Keisuke Onodera; *Makiko Ohtake; *Jun Kameda; *Matthew Izawa**
3) Number of students: **3**
4) Detailed description of the project (including aim, detailed plan and expected outcome):

Aim: The aim is to develop a practical understanding of remote sensing, lunar seismology, and hyperspectral imaging, with emphasis on their use in interpreting planetary surface processes. By working with both mission datasets and laboratory measurements, students will gain hands-on experience in applying these tools to problems relevant to planetary exploration.

Detailed plan: There will be three different projects focusing on Remote Sensing, Geophysics and experiments.
Remote sensing: This internship project will focus on landing site analysis particularly focussing on site assessment, characterization, and landing ellipse definition based on geological, topographic, and environmental constraints. Focussed on Japan's planned missions to Mars, the Moon, and potentially Venus, students will contribute towards the evaluation of safe and effective mission planning focussing on terrain stability, resource potential, scientific value, and operational accessibility.
Experiments: The experimental project uses the MISASA (Mars Innovative Simulator for Assessing Surface Aqua-environment) chamber and a laboratory hyperspectral camera (400-2500 nm) to simulate planetary surface conditions under controlled pressure, temperature, and illumination. Students will compare hyperspectral data from planetary analog materials and examine how spectral signatures respond to grain size, composition, and surface alteration, linking laboratory results with orbital observations to improve interpretation of remote sensing data.
Geophysics: The geophysics project introduces planetary seismology using Apollo lunar seismic records, with emphasis on shallow moonquakes as indicators of current tectonic activity. Students will work with short-period seismometer data together with the Apollo 17 Lunar Surface Gravimeter to identify seismic phases, estimate epicentral distances, and refine source locations under sparse network conditions. The analysis will examine how moonquake locations relate to surface tectonic structures and gravity anomalies, providing insight into lunar crustal processes and seismic hazards relevant to future surface missions.

Expected Outcome: The internship will lead to practical results that are directly useful for planetary exploration. Students will carry out landing site assessments and define landing ellipses based on geological, topographic, and environmental constraints, contributing to planning efforts for upcoming Japanese missions to Mars, the Moon, and possibly Venus. Laboratory work with the MISASA chamber and hyperspectral camera will produce reference spectra under controlled surface conditions, allowing students to relate spectral behaviour to grain size, composition, and surface alteration and to better interpret orbital observations. At the same time, analysis of Apollo lunar seismic data will refine the locations of shallow moonquakes and examine their relationship to surface tectonic features and gravity anomalies. Together, these activities will train students to work across remote sensing, experiments, and geophysics, and to apply these skills to real problems in planetary surface and subsurface studies.

N.B. Selection will be made following a brief interaction with shortlisted students. Additional details of the project will be shared with selected candidates at a later stage.